III. CONCLUSION

This chapter presents our findings in generalized, theoretical terms. This, it is hoped, will facilitate the formulation of conclusions that can serve as a basis for dialogue with those immediately concerned with the problems of technological development in the developing countries.

We have arranged our findings under the following eight closely interrelated rubrics by order of historical and logical progression:

1. The role of the state in technology transfer
2. National consensus for development
3. Formation of technology on the national level
4. Manpower and the diffusion of technology
5. Technical and social division of labour
6. Management as technology
7. The linkage of technologies
8. Developing dialogue

1. THE ROLE OF THE STATE IN TECHNOLOGY TRANSFER

With the establishment of the nation-state, the formation of a national economy became a supreme goal in each country. Technology transfer has since become an important means of achieving national economic independence. Looking back over history, one can see that technology transfer has often spurred the development of technology itself. However, in the past, transfers of technology occurred largely on an individual, unorganized, and haphazard basis, and the diffusion of innovations was slow, painful, and accompanied by many cases of failure. Moreover, it is important to distinguish between traditional transfers and those that concern us today. We can no longer afford to take chances with technology transfer.

It is characteristic of modern societies that planning for technology development on the national level is often carried out by the state, regardless of the political system. Projects involving technology transfer for national development, too, are mostly state-controlled. The role of the state in technology transfer is twofold. It determines what technology is most suitable to the conditions, natural and social, obtaining in that country and the timing of its introduction. It also fosters the kind of environment most conducive to the successful implantation of that technology.

The right choice of a technology may be hindered by the fact that a country's perception of technology itself is vague and inaccurate. Technology is often thought of as being universally applicable, like science. However, as we have noted, technology is shaped by the particular conditions that attended its development and its mode of application, although, to be sure, technology is based on scientific principles and therefore has a universal aspect.

The conditions determining technology include the density of scientific knowledge in the country of origin, the extent to which related technology has been developed, the level of skills, the needs of the market, the availability of natural resources, and the development of a transportation network. In other words, without these supports, technology cannot be properly or effectively utilized and developed. When technology is transferred, its link with the milieu of origin is severed, and the technology transplant occurs under different conditions. A successful transfer therefore depends on the creation of new linkages in the host milieu. Accordingly, in selecting the technology to be transferred, special attention should be paid to its distinctiveness and the potential for creating such linkages in the host country.

After selecting a technology, a developing nation must begin establishing the linkages that are necessary to support it. These include legal and financial measures, but the primary task is making technical education available on a wider scale and training technicians and engineers, a subject to which we will return.

Since countries differ considerably in their cultural and physical endowments, a transplanted technology acquires new traits from the new host environment. This is called the "transformation of technology." It is desirable and even necessary in view of the fact that a ready-made technology capable of overcoming the difficulties confronted by countries on the road to national development does not exist. Ultimately, it is up to each nation to create the technology that best corresponds to its needs. The important point is that because of technology transformation, even transferred technology can contribute to technological self-sufficiency.

In the initial period of Japanese industrialization, the government did not always plan carefully the introduction of technology taking into account its distinctiveness and specific linkages. The technology actually borrowed proved extremely diverse both with respect to level of development and scale. But a few industries managed to improve productivity to an extraordinary degree, establishing links with traditional industries having reached a comparatively high level of sophistication. These were the silk-reeling and cotton textile industries and metal and coal mining.

A vanguard technology that was unsuccessfully introduced from abroad because linkage was ignored is the iron-making industry. Where blast furnaces designed in Europe were brought in without regard for their ability to use Japanese raw materials, without proper planning for fuel procurement, and without paying attention to labour conditions and marketing, they performed very poorly and were subsequently abandoned. This equipment would probably have been relegated to the museum as past failures had it not been for a Japanese engineer who improved the furnaces, making it possible to use them in production. He was a product of the government's training programme for scientists and engineers. Besides Western techno-science, these specialists were familiar with Japan's traditional iron-making technology and the distinctive qualities of Japanese raw materials. The existence of such native engineers is the key to the successful implantation of foreign technology and its symbiosis with Japan's endogenous technology. Even today, the initial failure of the iron industry serves as a useful reminder to Japanese scientists and engineers of the importance of adapting foreign technical imports to local realities.

For the diffusion of technology it is extremely important to standardize at the earliest possible time national weights and measures, the number of cycles (hertz) for power supply, the gauge of railways, etc.

Failure to do so has resulted in Japan's having two different power cycles today instead of one nationwide norm. The reason is that technical specialists in the government initially did not appreciate the importance of imposing a system of standardized measurements on the whole country and left the introduction of foreign technology up to the private sector. Japan has been paying the social costs for this oversight for over a century.

Finally, it should be pointed out that in today's world, technology transfers should go both ways, from industrialized to industrializing countries and vice versa. Technology in the industrial countries is embedded in dense networks of wide-ranging but tightly interrelated technical fields and second support services from within it cannot be separated. Given such tightly woven networks, technological development may be stimulated in particular fields, but the networks themselves are incapable of stimulating technological development outside of these circumscribed areas. The build-in rigidity of technological innovation explains the attention that is being devoted to vanguard technology in the advanced countries and the critical and even hostile attitudes that are surfacing there toward technological development in general. Thus, in both the developing and industrialized countries, people have a stake in the evolution of new technologies in the developing regions. In fact, Japan has already borrowed "greenification" technology developed independently in the Republic of Korea. Another example of a technology that Japan could not have developed itself is the irrigation facilities developed in Taiwan for the two-way conversion of wet and dry fields. Needless to say, future technology transfers from developing countries will not be limited to agriculture and forestry.

2. NATIONAL CONSENSUS FOR DEVELOPMENT

The formation of a national consensus is important in enabling a country to cope with the impact of technology transfer. Inevitably, the introduction of advanced technology produces a variety of short-term and long-term social impacts at both the national and local levels, and this gives rise to social tensions and political unrest. In particular, a conflict often arises between the needs of the state and the basic human needs of the nation concerning the selection of technology to be imported. This may very well lead to political instability and call into question the state's policy and philosophy regarding technology and technology transfer. Such a clash can only be resolved in the political arena. Political stability is a condition for technology transfer based on a long-term development strategy. At the same time, stability is the result of a successful adjustment between competing needs in the process of technology transfer.

Tension between state requisites and elementary human needs occurs in all countries and at all levels of development. Generally speaking, however, state needs tend toward high-level technology for heavy industrial development (sophisticated, costly machinery) and the creation of infrastructures. Fundamental human needs are best satisfied by agricultural development and light industrial growth geared to consumer demand. Meeting state needs is indispensable for internal stability and the establishment of national sovereignty, but satisfying essential human needs is also an urgent priority in view of the serious population and unemployment problems faced by most countries. Resolving these problems can help to alleviate social tension.

For government, the key to maintaining stability in the face of these urgent needs lies in achieving legitimacy through the creation of a national consensus. This is difficult in a nation characterized by a low level of social integration and a loose social structure, for the constituent elements of national society may have different political cultures and orientations. To make matters worse, the earlier the stage of development, the more unequally the benefits of growth are shared by different regions, classes, and ethnic groups. This, too, engenders dissatisfaction and resistance to development.

When a national consensus cannot be formed easily because of social disequilibria, a charismatic leader often appears on the scene. He has a great functional value since the nationalistic feelings that such a figure inspires quite often play a decisive role in consensus formation. If such a consensus is threatened, political leaders may resort to chauvinism and fan xenophobic sentiment in an effort to reconsolidate national consensus. This should be considered a typical political reaction accompanying technology transfer. In the process of technology transfer, and particularly in determining the distribution of profits, it becomes clear whether the technology supplier is interested in contributing to the national formation of technology in the recipient country or whether it is motivated solely by gain. History shows that it devolves on the host nation to make key decisions in these areas. Only through such a process can the national consensus attain maturity.

It should be emphasized that the supplier of technology shares responsibility for formation of a national consensus in the recipient, or host, country. Technology donors have often interfered in the domestic affairs of the recipient in order to heighten political stability. Such interference is not in the long-term interests of either party. Furthermore, technology donors tend to impose their culture on the recipient because of the mistaken idea that advanced technology is proof of cultural superiority. Different cultures cannot be ranked in terms of relative superiority or inferiority. Failing to realize this, the Japanese elite has frequently erred in the past. Diversity in national cultures is of greater value in development than cultural homogeneity, and technology transfer should enhance, not destroy, cultural identities. This being the case, a national consensus may be formed in different ways and once formed, maintain its distinctiveness. Only then can it cushion the impact of technology transfer and promote internal political stability.

3. FORMATION OF TECHNOLOGY ON THE NATIONAL LEVEL

The ultimate goal of industrial growth through technology transfer is the national formation of technology. This requires the transformation, or "naturalization," of the foreign technology via the creation of linkages. Here we would point out that the overall national formation of technology requires the deconcentration of sophisticated technology in particular fields. Dense technology clusters must not only be gradually reduced, but eventually eliminated.

In the initial stage of late-comer industrialization, a major technology gap is apt to arise between the state, or public, sector and the private sector. Since private capital accumulation is still in its early stages in such countries, it is only natural that industrialization is usually carried out under state leadership which mobilizes state capital for investment purposes. Modern technology and the economy are inseparable, and the scale and level of technology are generally proportional to the quantity of capital available. This results in a structural technology gap between the two sectors.

The technology gap may be narrowed if government economic policy is successful in distributing economic benefits equally among the general public and in enhancing national economic growth. As the national economy expands, state and private needs become diversified and grow both qualitatively and quantitatively. However, the state sector, which is managed by the national bureaucracy, finds it is no longer possible to meet these burgeoning needs adequately and has to accept competition from the private sector, which has been gaining ground.

When this happens, a key question arises to confront national policy makers. When, to what extent, and in what areas should technological development be left up to the private sector? Here the validity of the government's philosophy of social and economic development is put to the test. The answer determines the direction of national technology formation and development.

Japan's initial industrial policy was that of fostering government-run heavy industry for the purpose of laying an industrial infrastructure and meeting military needs. Civil needs were left up to the private sector. As a result, there developed a permanent structural gap between the public and the private sectors, industry and agriculture, heavy and light industries, large and smaller enterprises, and central and local areas. This dual economic and technological structure is typical of late-comers to industrialization.

Military-related industries can pursue technological innovation without worrying about economic factors and may reach a more advanced level of sophistication than technology in general. But such industries cannot raise the overall technological level unless they establish links with other sectors of the economy. Without proper linkage, even military-industrial production may fail to develop. For example, although Japanese fighter aircraft of the prewar and wartime periods displayed outstanding design features and embodied an advanced stage of technology, this technology was not tied in to the national technological substructure. Materials for the main parts of such aircraft came from abroad, and the aircraft were produced by handicraft methods with no possibility of shifting to mass production.

It was not until postwar reforms had democratized and demilitarized the economy that balanced, truly national technology formation at the high level got under way in Japan. Under such reforms, technology transfer proceeded apace, opening the way to technical innovation. Although structural dualism did not disappear, areas of the economy opened up where smaller scale production proved to be optimal for technological innovation, affording a new perspective on economic growth.

Next, it should be pointed out that the endogenous capacity for technological development plays a decisive role in the national formation of technology. This can be better understood if one considers the implantation process of technology transferred as consisting of the following stages: (a) operation, (b) maintenance, (c) repair, (d) imitation and/or modification, (e) design, and (f) domestic manufacture based on the new design.

Imitation or modification is extremely important in the initial stage of national technology formation. Since the Western technology introduced in the initial period of Japanese industrialization consisted mainly of combinations of technology that dated back to the mid-nineteenth century, it was possible to produce substitutes and imitations as artisans accumulated experience by carefully dismantling and repairing overseas machinery. These substitutes could not match the original models in terms of durability, efficiency, or performance, but they could meet the needs. The important point is that craftsmen began reproducing this machinery in areas where the technology gap vis-à-vis the West was relatively narrow. This experience served as the basis for modernizing traditional sectors. It was also instrumental in expanding technological capacity and passing from the stage of imitation to modification and on to that of original design and production.

Looking at the same sequence from a different angle, the first stage can be characterized as the handicraft stage, in which many similar or substitute products are produced, one by one, in small quantities. The second stage is one of production by machinery involving the formation of new skills; factory industry is established to overcome seasonal constraints on production. The third stage is characterized by the mass production of standardized products, where total quality control becomes an important constituent element of technology. The next stage is that of gigantic production schemes which make use of mechatronics to produce in small quantities a wide variety of products incorporating a high degree of value added. This does not mean that new stages entirely displace older ones, but merely that the former take over as leading sector. In other words, the co-existence of all stages is a condition for the development of a total system of national technology.

Finally, it should be noted that Japanese engineers played a unique role in the process of national technology formation. In fact, the existence of the Japanese-type of engineer has been a key element in insuring Japan's technological independence. First, Japanese engineers have almost all been nationalists, and this has avoided a brain drain. Second, Japanese engineers have not hesitated to take direct control of production when required, sometimes standing in for foremen or highly skilled workers who were in short supply. This versatility has created a close relationship between R&D and production. Third, thanks to their first-hand experience in production, Japanese engineers have shown an exemplary ability to develop kinds of technology that make possible production stability, eliminate bottlenecks, make production easy and safe, and reduce maintenance and control difficulties.

These characteristics also typify the craftsmanship that is such an ingrained feature of the Japanese worker or craftsman. Techno-scientists were not the only ones to go abroad to learn advanced technology in the first stages of Japanese industrialization. Many skilled craftsmen visited international expositions abroad with assistance from the central or local government, or even their own professional associations. There they learned new techniques and processes, bring back new equipment as well as machinery and tools. Instead of keeping their newly acquired technology to themselves, they frequently exhibited foreign products at industrial fairs, demonstrating their use, and thereby contributing to technological improvement and the wider diffusion of new technologies. The large number of skilled craftsmen who went abroad made it possible to modernize traditional technology and combine it with modern technology.

Government programmes were also set up to train engineers, and technical schools turned out large numbers of engineers and skilled workers. Engineers went into the field to give in-service training to workers and in so doing gained valuable first-hand experience themselves. In such cases, the workers in the field assessed the ability of the engineers primarily on the basis of how they handled technical problems that arose. It was not uncommon for them to disobey the instructions of engineers who were not proficient at problem solving.

In general, engineers and skilled workers in Japan have displayed a strong team spirit, and it is this that forms the backbone of production technology systems within companies. This also explains why, in general, there is so little "job hopping" in Japanese society.

4. MANPOWER AND THE DIFFUSION OF TECHNOLOGY

This chapter contends that technical education and the training of engineers are important areas of government policy-making that have a direct bearing on technological independence and national technology formation. Policy here should aim at increasing the variety and absolute number of engineers, making them a distinct social stratum. A system assuring fair competition and co-operation among engineers should also be established.

In the early stages of technology transfer, the absolute number of technicians is small, and engineers tend to be evaluated in terms of their ability to formulate technology policy based on the collection and analysis of data. Since this information is foreign-derived, proficiency in foreign languages tends to be overemphasized. However, once technology transfer takes place, the ability of engineers to take charge of operation, maintenance, repairs, and control becomes a decisive factor. Thus, a feedback mechanism to monitor technical competence at the production level and policy formulation is indispensable in successfully transplanting technology and building links among the technologies transferred. Without free and frequent communication between techno-scientists and engineers, the two will confine themselves to their own separate areas of concern, leading to technocracy.

Technology gains in stability by developing horizontally and attains greater sophistication by developing vertically. Linkage is created between a variety of sectors when technology evolves in both of these directions at once. The creation of in-depth linkages and the active participation of all social strata in technological development are of paramount importance to national technology formation.

The populace may not be conversant with the grammar of science, but it does have a wealth of resourcefulness and skills based on experience from which to draw. The scientific content of these skills and accumulated wisdom can be discovered and confirmed only by native engineers, certainly not by foreign experts who know almost nothing about the local culture. Where native engineers organize the resourcefulness and skills of the nation, popular participation in the development process increases, and this, in turn, contributes to the wider and speedier application of new technology. Moreover, in so doing native engineers can find opportunities and hints to upgrade technology.

The groundwork for national technology development is made still more solid and effective through the diffusion of scientific and technical education in the national language. Surprisingly, however, in developing countries it is often techno-scientists themselves who oppose such education on the grounds that it will compromise scientific and technological excellence. The fact is that technology can be consolidated and improved if it evolves both horizontally and vertically and linkage is successfully established between the two sectors of development. Unless the overall level of science and technology is raised, high technology will not be incorporated into national technology. Accordingly, it is imperative that large numbers of books on science and technology be published in the local language and read widely at both the introductory and advanced, or specialized, levels. Furthermore, a low literacy rate can be at least partially overcome through the effective use of illustrations, slides, and tapes.

It is often maintained that another obstacle to the wider application of modern technology is the conservative nature of peasants, artisans, and other social strata. We do not share this view. Peasants and artisans are extremely wary about new technology that has not yet proved its value; their very survival is at stake. Once the usefulness of a technology has been sufficiently demonstrated, they are more than willing to adopt it. Much more needs to be done to find ways of harnessing this potential energy.

If these energies are not, or cannot be, mobilized, the problem is likely to lie not in the level of technology or skill per se but in the underlying social structure. In other words, one must consider the class character of technology in society. In such cases, the task of the government is to liberate technology from its closed class structure and make it accessible to society at large.

The difficulties in doing so are enormous, but a number of measures can be taken toward this end. They include encouraging broad popular participation, providing scientific and technological education in the national idiom from the elementary to advanced levels, and institutionalizing the training of a large number and variety of engineers. Fair competition and co-operation should also be assured among them and a feedback mechanism created as described above. By such efforts, it will be possible to produce indigenous engineers who are capable of identifying the technology best suited to the conditions and culture of their own country.

Modern and traditional technology are two different things, and the first task confronting indigenous engineers is that of bridging the gap that separates them. When transferred technology serves as the driving force in national technology formation, that gap must be bridged repeatedly.

Where new technology is concerned, it assumes a form quite different from that of traditional technology, and the mechanisms involved are often very complex. Accordingly, new kinds of engineers, skilled workers, and managers are needed to make the most of these new areas, and this entails continuous, systematic training by steps. In other words, occupational training and specialized education at all levels is absolutely indispensable.

In Japan, techno-scientists volunteered to train foremen before engineers in the real sense of the word appeared in large numbers. They did this by teaching evening classes. Although many of them practically worshipped modern Western technology, they also fully realized the urgent need to train foremen and were willing to offer their services for that purpose.

The first school offering full-time programmes for training foremen in Japan was the Tokyo Worker Training School founded in 1881. It later became the Tokyo Institute of Technology. Thanks to its founder, an outstanding engineer, and his competent successors who transmitted his philosophy of technology, this school was able to play a key role both in finding wider applications of technology and in improving on it. Particularly significant is the fact that many of its graduates became teachers in schools modelled after it and established throughout the country.

National technology formation has two aspects: the transplantation of modern industry, and the modernization of traditional industry. The latter involved both urban and local traditional industries, and the modernization of both types spread throughout the country via technical apprentice schools set up for this purpose.

Although the technical apprentice schools were not looked on kindly by artisans dedicated to excellence in craftsmanship, they gradually came to produce new leaders in local industry, thereby improving the technical level of traditional industry.

As the level of technology rose, basic and advanced scientific knowledge -- requiring a high level of education -- became an absolute prerequisite for acquiring advanced skills. In answer to this need, many different kinds of schools came into being. These included technical apprentice schools, vocational schools, and higher technical schools. Within only fifty years or so, the Tokyo Worker Training School had become the Tokyo Institute of Technology. It is also interesting to note that although the higher-level schools were incorporated in the national school system set up under the Ministry of Education, vocational training was not initially under the control of that ministry. It was linked to the activities of the Industrial Laboratories and Agricultural Experimental Stations established throughout the country by the technology departments of various ministries.

Government-run projects and model factories played an important role in the vertical, top-down diffusion of technology. The Meiji government undertook to transfer foreign technology to Japan in many areas in an impetuous and at times even rash manner. Moreover, bureaucratic control over the facilities established to make use of this technology resulted in deficit operations. This situation was compounded by the deterioration of the government's financial position as a result of civil war. In the end, the government sold these facilities, including mines and model factories, to the private sector but kept military industries and other basic public sector facilities needed by the state. When the facilities were sold, the engineers and workers there were reassigned to the new owners, and this meant that henceforth technological competence would be evaluated in economic terms. "Political merchants" frequently became the new owners of former government property by using their pull with well-placed politicians, but in these cases, only those with technical ability or managerial skills managed to hold onto their businesses for very long.

5. TECHNICAL AND SOCIAL DIVISION OF LABOUR

One of the most important elements in "catching up" rapidly is a rational technical division of labour in production and the rotation of labour between different production processes.

When Japan began the large-scale production of cotton yarn with foreign technology, India was already well ahead of it. However, in less than ten years, Japan managed to catch up with India in the area of low-count yarn and suppress imports of such products. By the end of the last century, it had even become a net exporter of them. Until now, this is thought to have been made possible by a combination of low wages and the introduction of up-to-date technology, such as ring frames and electric lights. A macro-economic explanation, however, does not fully explain why Japan was able to catch up so quickly.

In order to compete with India, Japan introduced a thorough-going rational technical division of labour. It raised the number of individual manufacturing processes in the original Western production scheme and subdivided different kinds of work within each individual process. This produced two effects: first, it sped up the formation of a partially skilled work force at an early stage; second, it deployed male and female, young and old workers in proper work processes.

Moreover, by rotating workers between the rationally divided subprocesses, it was easier to learn and master the entire process step by step. This helped create foremen with a knowledge of the technical relationship between earlier and subsequent manufacturing procedures and capable of dealing with the technical problems that arose encompassing several different processes.

The technical division of labour in the early period served as a training school for skilled manpower, even after the technical structure had evolved, becoming more specialized, and overall production had developed into a complex system. The existence of people with specialized skills and skilled workers familiar with related areas of production helped to smoothly assimilate increasingly sophisticated technology.

But in India's case, the technical division of labour was founded on socio-cultural differentiation, and this made it incapable of undergoing rational change. The free rotation of labour was therefore not possible.

Needless to say, each country has to improve and consolidate technology in its own way, and the Japanese formula for developing the technical division of labour may not be the most suitable everywhere. Nevertheless, it merits close attention.

Developing the technical division of labour has a spin-off effect. With the thorough subdivision of production in all industrial fields, the chances of a particular process or subprocess evolving separately are heightened, resulting in the further growth of smaller businesses and the social division of labour. This plays a positive role in stimulating entrepreneurship, but in actual practice, this kind of spin-off is often characterized by technological and financial subordination to the parent company. Unless it shows managerial acumen and an ability to promote technological growth, the subsidiary runs the risk of being discarded by the parent company as the latter continues to innovate. Fortunately, some subsidiaries have lately developed a considerable capacity for innovation, sometimes even surpassing the parent company in some areas of technology. These firms have become more independent and are now an important constituent element in Japan's overall technological development effort.

However, looking at national technology as a whole, structural dualism still persists. This is evidenced by a complicated labour structure where "outside" workers hired by subcontractors or sub-subcontractors work together with temporary and seasonal workers alongside the company's own employees in the same factory.

If the technical and social division of labour are not properly geared to the flow of production, or if the different production processes are too autonomous, technological innovation may prove disruptive.

In the case of the world-famous Swiss mechanical watch industry, for instance, each of the component parts was produced by very independent manufacturers. The famous makers were nothing but outstanding designers and precision assemblers who rigorously controlled the quality of the parts. Since production was not vertically integrated, no watchmaker had an overall view of the entire production sequence. As a result, the Swiss got a late start in quartz vibration technology, although the principle had been discovered almost half a century before.

The Japanese watch industry, on the other hand, which began by importing and repairing Swiss clocks and watches, took roughly a century to develop into a precision machinery industry. During that time, the technical and social division of labour in the industry was reorganized a number of times, and a vertically integrated production system was refined continuously. As a result, Japan was able to begin manufacturing quartz clocks and then quartz watches, having achieved overall mastery of the production processes. Eventually, Japanese watch manufacturers combined liquid crystal technology with electronics to produce digital watches.

Although improving the technical and social division of labour is an effective method of catching up, it does not necessarily lead to technological innovation in all fields. It should also be noted that the technical and social division of labour reflects the history of national technology formation. This history is specific to a particular national experience and cannot serve as an a priori model for all other countries.

6. MANAGEMENT AS TECHNOLOGY

There is an indivisible relationship between hard technology and management, the nature of the former being affected by that of the latter, and vice versa. Management is a kind of soft technology. It can be built up on the basis of universally valid management principles. But at the same time, management should be able to incorporate changing technology endowments and accommodate the technical level of engineers and skilled workers and the socio-cultural traditions of each country.

Today the techno-scientific principles built into finished products and equipment are tried, tested, and well-known. Manufacturing is now primarily a matter of "know-how." This know-how comprises the technological capacity of individual firms. In view of the tremendous investment in time, money, and talent, firms use patents and other methods to protect it.

Specifically, a firm's design capability depends on the use to which it puts the overall technological skills of its engineers and workers in meeting real and potential market needs. The importance of technological competence is growing, and there is a trend toward the participation of engineers in top management in firms in the processing and manufacturing sectors.

Skilled workers are indispensable for technological progress, but they are always in short supply. In order to deal with the shortage of skilled workers and achieve a high level of efficiency, corporations introduce skill-saving machinery such as numerical control machines and robots. But since the creation, repair, and improvement of these machines depends completely on advanced human skills, the level of technical competence required must continue to rise. As a matter of fact, although mechatronic automated lines now constitute the mainstream in the leading sectors in Japan, old lines are kept operating in a number of firms in order to preserve necessary skills.

But, if numerical-control machines and automated systems are used exclusively to replace human skills, the result might be increased unemployment. The ensuing social tension would not be in the interest of business, however, and for this reason such innovations must be accompanied by an overall upgrading of skills and technology in the context of national technology formation.

Being a kind of soft technology, "Japanese style" management has evolved, but one constant feature both before and after the war is the relative separation maintained between ownership and management. In the prewar zaibatsu concerns, represented by such names as Mitsui and Sumitomo, ownership was a closed, family affair; management was the almost sole responsibility of salaried managers with a high level of education.

A second "Japanese" feature is the fact that the greater the technological span of a firm, the more pronounced is its tendency to increase internal capital reserves instead of raising dividends as a way of distributing earnings. The internal reserves are earmarked for future technology transfer and development. Behind this practice is the belief that winning in stiff competition to develop continuously is the greatest contribution that shareholders, employees, and clients can make to national society.

Japanese management features became still more pronounced during the democratization of Japanese society after its defeat in 1945. The closed ownership by one family of prewar days ended with zaibatsu dissolution. Today, the proportion of company stock owned by individual shareholders is extremely small, most shares being held by institutional shareholders, such as affiliated companies, banks, and life insurance firms. By providing an element of stability, they insure the salaried managerial class its broad discretionary power over management.

Salaried managers, for the most part, rise from the company ranks. Their professional skills are developed during a long period of apprenticeship and through practical experience within the company, and they are completely effective only within that company; management skills are not transferable from one company to another. This being the case, managers very rarely change jobs, although they may move to other companies in the same corporate group.

New regular employees on whom the future of the company depends are usually hired once a year by examination. This is true of both college graduates, who will be groomed for future executive positions, and high school graduates, who will be assigned to the company's operational, or line, units. Working their way up the promotion ladder, they are gradually screened over a period of ten or fifteen years. At each step on the ladder, they receive further training and are tested for supervisory ability, technical competence, and managerial skills. By virtue of their assignments to different posts throughout the company, they become familiar with all aspects of company operations and are able to participate in detailed, long-range corporate planning.

The Japanese company's propensity to strive for long-range development has become even stronger since the end of the war. The increase in stable institutional shareholders has given management nearly absolute discretionary powers. Unlike their American counterparts, who are subject to pressure from shareholders to maximize short-term profits, Japanese managers are free to concentrate on medium and long-range company strategy, including the risky introduction of new technology, investment in plants and equipment, and research and development.

It is important to note that Japanese labour unions are also "company" unions. The difficulty of establishing national unions along occupational lines can be explained by the fact that workers, too, participate in their company's internal promotion system. Workers also tend not to change jobs, partly because their skills are not entirely transferable either.

Another typical "Japanese" feature is that some company unions include both white and blue-collar employees without any distinction. The often inherent differences of interest that separate white and blue-collar workers are resolved by compromise within the union, which is able to exert strong influence on management because of its broad organizational base.

Much has been said regarding the traditional cultural background that underlies Japanese management practices. The most popular explanation is that this system is derived from the family and village traditions of Japan. Our position, however, is that while socio-cultural tradition is one element, it does not automatically lead to a "Japanese style" management system.

Japanese management also has dysfunctional aspects. For instance, unemployment among employees over 55-60 years of age is a major problem. The regular hiring of recent high school or college graduates and the internal promotion system combine to force employees out of the company as soon as they reach the mandatory retirement age. Although the companies do their best to arrange new jobs elsewhere for retirees, not everyone is fortunate enough to find a suitable position. Nevertheless, since there are no layoffs, except under very unusual circumstances, unemployment among the young is not high, and overall unemployment is kept at a low rate.

A more pressing problem is the fact that the highly integrated and efficiency oriented Japanese management system tends to work against the development of public spirit and a sense of social responsibility. The classical manifestation of this is industrial pollution. One of the reasons why this problem has been late in surfacing in Japan and has proved particularly complicated to deal with is that labour unions, integrated into the corporate structure, have co-operated with management in its efforts to conceal internal sources of pollution.

7. THE LINKAGE OF TECHNOLOGIES

Japan's mixed experience of success and failure in technology transfer, transformation, and development would appear to suggest that developing countries might give more consideration to the linkage of technologies.

Any country has, of course, some degree of natural technology linkage. The use of iron for the blade edge of wooden ploughs is a case in point. The quality of the main part of the plough depends on the craftsmanship of the carpenter, and that of the blade edge depends on the skill of the blacksmith or the state of technology in a modern ironworks. Another factor determining plough quality is the quality of the iron that goes into the blade edge. Several different kinds of linkage may be involved depending on whether the iron was made in a backyard furnace, by a large or small modern ironworks in a developing country, or by a multi-national corporation (MNC).

There are different types of technology linkage:

(1) During Japan's Tokugawa period, technology had already reached a fairly high level of development without the theoretical insights of modern science. But, at the same time, in all areas of production, it had reached a ceiling and begun to stagnate. At the risk of being misunderstood, one can even say that further qualitative improvements of technology had become impossible. There was no leading sector capable of raising the overall level of national technology. In other words, the linkage of the Tokugawa period was static linkage. Static linkage can at least be represented in theoretical terms, and one can imagine a vicious circle resulting in stagnant equilibrium.

(2) In contrast to static linkage, we propose the concept of dynamic linkage, i.e., linkage characterized by a chain reaction in which technological progress or innovation in one area results in technological progress in others. This type of linkage has been very much in evidence in Japan since the Meiji period, a good example being the cotton spinning and weaving industry. Japan imported state-of-the-art spinning machines from abroad and set up large-scale mills which were run successfully on a permanent basis. Most of these spinning mills did not, however, engage in weaving at the outset, for most Japanese wore clothes made from narrow cloth; there was no market for the broad cloth produced by European power looms. As a result, narrow cloth continued to be woven by hand for quite some time. Hand-weaving techniques were able to survive for so long partly because of low wages and the lack of full employment. But another reason was the improvement in the quantity and quality of hand-woven goods due to the more even quality of the cotton yarn supplied by modern spinning mills, which supplanted traditional hand-spun yarn. In other words, linkage between new and old technologies made it possible for both

to develop in a mutually complementary fashion. Needless to say, the driving force behind dynamic linkage was the technology employed in the modern spinning mill.

Linkage existed in traditional society as well, but colonial rule destroyed it in many nations, resulting in what can be termed dislinkage. Today, MNCs are a cause of new dislinkage. "Enclave production" is one example. The advanced technology and high productivity characteristic of the MNCs has very little, if any, secondary, tertiary, or successive beneficiary impact. Even if linkage is created in a configuration with the MNCs at the apex and results in producing beneficial effects, the developing countries pay for it in terms of technological and economic subordination to the MNCs. It is in consideration of this fact that we attached so much importance to the role of the sovereign state in chapter I.

Dynamic linkage may be subdivided into linkage based on the needs of the civilian population and linkage based on military needs. Since the Second World War, dynamic linkage in Japan has been predominantly based on non-military requirements. Almost all research and development funds have gone to meet civil needs, and the resulting technological improvement and innovation have contributed directly to higher productivity.

When linkage based on military needs is concerned, research and development do not necessarily lead to technological innovation that is transferable to the non-military sector. Furthermore, even if military production leads to technological progress, military production itself has difficulty in creating close links with related technological fields which do not develop as rapidly.

Linkage takes place on a number of levels and scales. When technological linkage in one country is close-knit, the scale of linkage is large; if the country is large, the scale of linkage is even larger. However, even if the country is large, the scale of linkage may remain small due to given historical and international conditions or the wrong choice of technology. Here dislinkage may also be a factor.

If high technology is linked with related areas, the level of linkage is also high. This is considered ideal.

But if the level of technology is too advanced for the level and scale of national technology, ideal linkage will not be created. For instance, although KS magnetic steel, invented by Kotaro Honda in 1917, represents a momentous modern scientific achievement of which Japanese can be proud, it was not in Japan but in the United States, with its higher level of technology and greater economic power, that it first found practical application, with the result that Japan ultimately had to purchase this technology from abroad.

A positive example is the series of improvements that were made to the power loom, and the subsequent development of the automatic loom (1924), by Sakichi Toyoda. These successes were possible because the new technology was compatible with the level and scale of the Japanese cotton textile industry, and its application resulted in a tremendous rise in the technological level of the industry as a whole.

The history of the Japanese automobile industry also substantiates this point. Before the Second World War, Japan was not able to establish a full-fledged passenger car industry. Although Japan produced trucks in large numbers, such production depended almost entirely on military demand and was not internationally competitive. In the case of Japanese motor vehicles, the level of technology in the machinery industry, and especially in the casting of engines, was particularly low, and adequate linkages could not be forged. After the war, however, the mass production of motor vehicles became possible as progress was made in related technological fields. The production and supply of steel of reliable quality provided was of prime importance in paving the way for automated mass production.

It should also be noted that if the level of technology in a particular area outstrips that of related technology by too great a margin, the former may retard the latter. We refer to this as disjointed linkage. A particularly serious kind of disjointed linkage is that obtaining between certain forms of technological development and the natural and social environment -- industrial pollution. Japan like other industrialized countries has had many failures in this respect, notably the widespread pollution caused by the Ashio Copper Mine in the late nineteenth and early twentieth centuries. Such disasters are the unfortunate result of going ahead with technology transfer and development without taking obvious necessary precautions or, when these were taken, of failing to apply them with the necessary thoroughness.

The proper choice of technology is a key factor in socio-economic development, and each nation must decide for itself which technology applied in what areas will result in dynamic linkage and not dislinkage. Once again, the particular conditions existing in a given country will determine the level and scale of the technology. Two points need to be re-emphasized here: the role of the state is of great importance in this endeavour, and only indigenous engineers are capable of exploring the possibilities of achieving permanent dynamic linkage.

8. DEVELOPING DIALOGUE

This concludes our theoretical overview of Japanese experience. The

Japanese experience is in many respects unique and difficult to generalize from. Nor, for the following reasons, do we pretend that it should be emulated by other countries.

First, Japan has experienced many failures, some of them decisive. Second, the world situation in which development is taking place today is markedly different from the circumstances in which Japan began to modernize in the mid-nineteenth century. In fact, the only feature that many developing countries share with Japan is that they, too, are late-comers to industrialization. This constitutes one of the operational premises of our theory. Third, Japan could modernize itself rather quickly partly thanks to its endogenous technology which had already reached a fairly high level when it started introducing modern technology.

Nevertheless, the seven points outlined above appear to have universal validity for national development. It is also true, however, that the applicability of these operative principles to local realities in developing countries can be ascertained theoretically only by confronting them with the conditions that obtain in each. In this sense, we look forward to the responses of experts, planners, engineers, and economists in the industrializing countries to this report and its sequels, which will be published later. It is our hope that this report will initiate a fruitful dialogue.

Our conclusions are supported by the specific facts of technology: as a result of our five-year project, we are thoroughly convinced that the problems of technology are specific in content and that abstract, philosophical arguments in this domain are doomed to sterility. The dialogue we hope to begin can bear fruit only if more advanced theoretical formulations are derived from the concrete experience of each nation.

We have adopted a value-free approach. Our project was not undertaken in order to confirm or invalidate a given set of hypotheses or theoretical approach.

In the course of our work, however, we have become increasingly convinced of the need, and indeed the inevitability, of a horizontal international technological division of labour. This, we feel, is essential for securing mutual co-operation and mutual interdependence on a regional and international basis. In this context, South-South and South-North technology exchanges, as opposed to North-South technology transfers alone, will no doubt play an increasingly important role.

An important theoretical task will then arise. That is the need to determine, through research, what scale of national technology formation is initially required by each country to enable it to participate fully in intra and inter-regional co-operation. What level and scale of technology will enable it to find a place in the international technological division of labour as an equal, indispensable member? We now see that this is an almost entirely undeveloped area of study.

This matter is too important to be left to the intellectuals of a particular geographical region, a particular school of thought, or a particular international organization.

The national experience of all countries must be studied comprehensively and synthesized so as to reveal its unique -- and equal -- contribution to the human endeavour. The Japanese experience will take its rightful place alongside other national experiences as worthy of study.

This intellectual task with its completely new perspective will necessarily require the active participation of researchers and scholars the world over.